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Yb:YAG ceramics with longitudinal doping gradient

Lead Beneficiary:

National Institute for Laser, Plasma and Radiation Physics, Bucharest, Romania - INFLPR

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Deliverable Nature	
R = Report, P = Prototype, D = Demonstrator, O = Other	R
Dissemination Level	
PU = Public PP = Restricted to other programme participants (incl. the Commission Services) RE = Restricted to a group specified by the consortium (incl. the Commission Services) CO = Confidential, only for members of the consortium (incl. the Commission Services)	PU

A. Abstract / Executive Summary

The work was aimed at developing a process for the production of 1-2 cm in diameter, transparent, laser-grade ceramics with longitudinal doping gradient with the goal of a better management of the thermal load and a mitigation of the ASE.

B. Deliverable Report

1 Introduction

The feasibility of producing ceramics with a longitudinal doping gradient had to be investigated. The properties of such laser materials concerning the peak temperature in laser applications needed to be compared for different compositions.

A new method for the production of ceramics was introduced, what is based on tape casting. The new method offers a great flexibility of the production process and of obtainable geometries. Its advantage is the possibility to produce materials with a finer longitudinal doping gradient. This gradient is made up of thinner layers of different composition. Samples were produced and their thermal behaviour compared.

2 Work performed / results / description

2.1 *Study of an experimental approach to the production of layered ceramic structures alternative to the one previously employed.*

The new selected process is based on the tape casting in combination with thermal compression of ceramic tapes with different doping layers. Samples with layers of undoped and 10-at.% Yb doped YAG and graded structure with 1-3-5-7 at.% were prepared. The method is illustrated in Fig. 1. The dopant distribution was carefully analyzed by SEM with EDX. The diffusion layer for samples made by tape casting was about 150 and 100 μm in the case of 0-10 at.% doping and 1-3-5-7 at.% doping, respectively.

2.2 *FEM simulations of the thermal behaviour of layered structures.*

The dependence of the thermal conductivity on the doping level was also taken into account (this issue was neglected in the previous set of simulations). The following geometries were simulated:

case #1	→ uniform doping	(3 mm)	5-5-5-5-5 (% Nominal doping in YAG)
case #2	→ low graded	(3 mm)	3-3-5-5-7
case #3	→ high graded	(3 mm)	1-3-5-7-7
case #4	→ step grading	(3 mm)	0-0-10-10-10
case #5	→ capped (both sides)	(3 mm)	0-10-10-10-0
case #6	→ thin	(2.4 mm)	10-10-10

Figure 2 shows the maximum temperature difference for the different cases.

2.3 *Optical characterization of the ceramics structure.*

Using a similar setup as the one previously reported, a set of measurements was carried out aimed at comparing the 2 production methods used (Tape Casting and Pressing of Spray Dried Powders). The results show that both the TC and PSDP techniques are capable to produce samples with quite high slope efficiency (around 54-56% for the most favourable output coupling condition), as long as a small number of individual layers with different doping is used.

2.4 *Experimental study of the uniformity of the optical quality of the samples.*

The analysis showed that overall the samples made by TC have a lower density of large defects (size of tens of microns) as well as a better background transmission. The background transmission of the sample made by TC is around 80%, which reduces to around 72% for the sample made by PSDP.

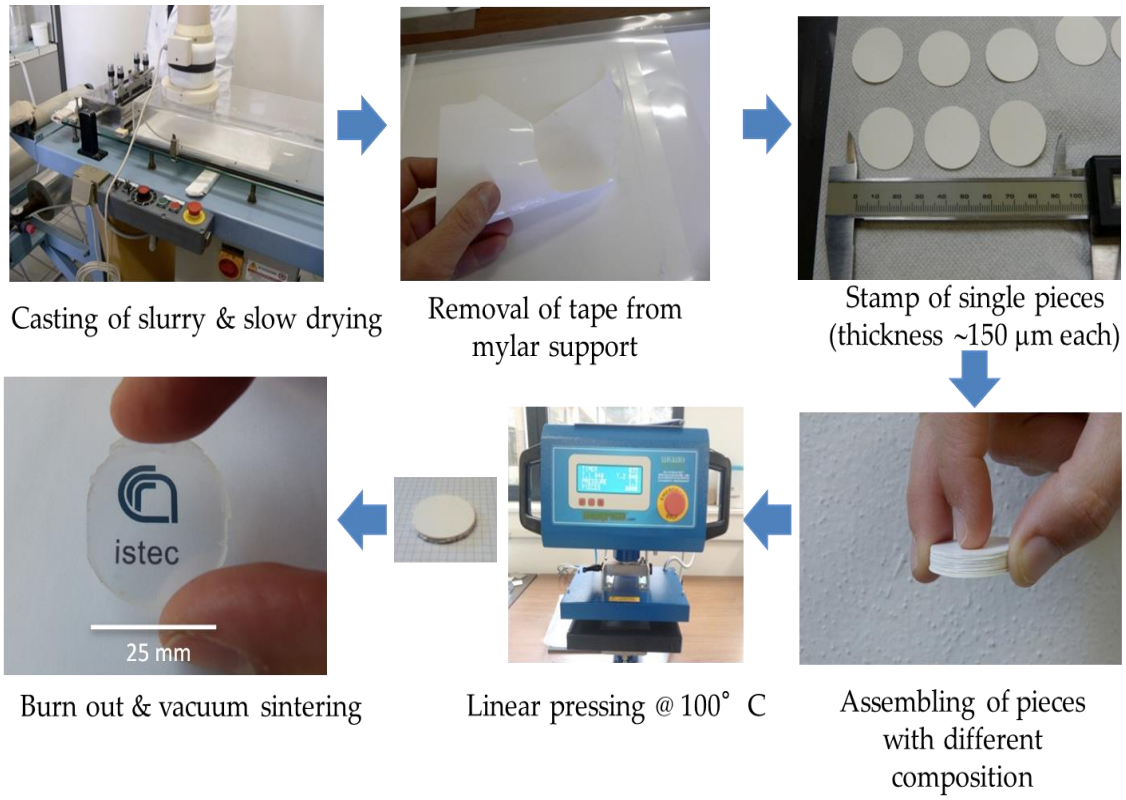

Fig. 1. Schematic illustration of the tape casting and thermal compression procedure.

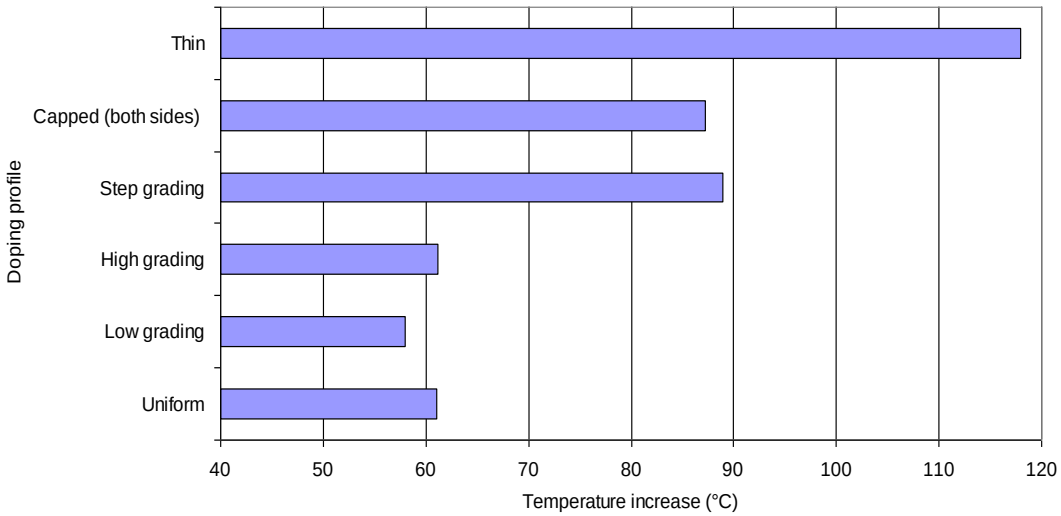

Fig. 2. Maximum temperatures in different hosts of the different structured YAG slab samples obtained with the FEM numerical simulations adopting the same power loads indicated in our first set of simulations (as reported in the first technical report of this same project).

3 Conclusions

Samples prepared by the new tape casting TC method show a lower density of large defects and lower loss. The Method allows a greater flexibility of the production process and of obtainable geometries. A couple of new ceramic samples were produced. These structured samples were investigated concerning their thermal behaviour in laser applications. It was found that well designed structures help to reduce the maximum temperatures and therefore allow in principle a higher power of laser output and better beam parameters. This clearly identify the method as a very powerful tool for the future production of high performance laser ceramics.

4 Publications

[1] L. Esposito, J. Hostaša, A. Piancastelli, M. Vannini, G. Toci: Complex layered SSL sources produced by a multipurpose, adaptable and fast ceramic process. 39th International Conference & Exposition on Advanced Ceramics and Composites (ICACC), Daytona Beach, Florida, 25-30 January 2015.

[2] J. Hostaša, L. Esposito, W. Pabst: Transparent YAG ceramics - the effect of doping ions. 39th International Conference & Exposition on Advanced Ceramics and Composites (ICACC), Daytona Beach, Florida, 25-30 January 2015.

[3] G. Toci, A. Lapucci, M. Ciofini, L. Esposito, J. Hostaša, A. Piancastelli, L. A. Gizzi, L. Labate, P. Ferrara, A. Pirri, M. Vannini: Graded Yb:YAG ceramic structures: design, fabrication and characterization of the laser performances. High-Power, High-Energy, and High-Intensity Laser Technology SPIE Optics + Optoelectronics 2015, Prague, Czech Republic, 13-16 April 2015.

[4] J. Hostaša, A. Piancastelli, V. Biasini, L. Esposito: Transparent Yb:YAG ceramic laser gain media, on the way to clean energy, Ceramics for Energy (CeN), International Workshop, Faenza, Italy, 14-15 May 2015.

[5] G. Toci, A. Lapucci, M. Ciofini, L. Esposito, J. Hostaša, A. Piancastelli, L. A. Gizzi, L. Labate, P. Ferrara, A. Pirri, M. Vannini: Graded Yb:YAG ceramic structures: design, fabrication and characterization of the laser performances. *SPIE Proceedings* **9513** (2015) 95130R.